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TREATMENT OF NEUROMUSCULAR DISORDERS AND CONDITIONS
WITH DIFFERENT BOTULINUM SEROTYPE

FIELD OF THE INVENTION

The present invention provides novel methods for treating diseases of the nervous system, e.g., neuromuscular disorders and conditions, with botulinum toxins. In addition, the present invention provides methods useful in all tissue and organ systems which involve the release of neurotransmitters, especially acetylcholine. These cholinergic transmission systems include neuromuscular junctions (muscles), smooth muscles (gut, sphincters, etc.) and secretions (salivation and mucus).

BACKGROUND OF THE INVENTION

A bacterial toxin, botulinum toxin, in particular botulinum toxin type A, has been used in the treatment of a number of neuromuscular disorders and conditions involving muscular spasm; for example, strabismus, blepharospasm, spasmodic torticollis (cervical dystonia), oromandibular dystonia and spasmodic dysphonia (laryngeal dystonia). The toxin binds rapidly and strongly to presynaptic cholinergic nerve terminals and inhibits the exocytosis of acetylcholine by decreasing the frequency of acetylcholine release. This results in local paralysis and hence relaxation of the muscle afflicted by spasm.

For one example of treating neuromuscular disorders, see U.S. Patent No. 5,053,005 to Borodic, which suggests treating curvature of the juvenile

spine, i.e., scoliosis, with an acetylcholine release inhibitor, preferably botulinum toxin A.

5 For the treatment of strabismus with botulinum toxin type A, see Elston, J.S., et al., *British Journal of Ophthalmology*, 1985, 69, 718-724 and 891-896. For the treatment of blepharospasm with botulinum toxin type A, see Adenis, J.P., et al., *J. Fr. Ophthalmol.*, 1990, 13 (5) at pages 259-264. For
10 treating squint, see Elston, J.S., *Eye*, 1990, 4(4):VII. For treating spasmodic and oromandibular dystonia torticollis, see Jankovic et al., *Neurology*, 1987, 37, 616-623.

15 Spasmodic dysphonia has been treated with botulinum toxin type A. See Blitzner et al., *Ann. Otol. Rhino. Laryngol*, 1985, 94, 591-594. Lingual dystonia was treated with botulinum toxin type A according to Brin et al., *Adv. Neurol.* (1987) 50, 599-
20 608. Finally, Cohen et al., *Neurology* (1987) 37 (Suppl. 1), 123-4, discloses the treatment of writer's cramp with botulinum toxin type A.

25 The term botulinum toxin is a generic term embracing the family of toxins produced by the anaerobic bacterium *Clostridium botulinum* and, to date, seven immunologically distinct neurotoxins serotype have been identified. These have been given the designations A, B, C, D, E, F and G. For further
30 information concerning the properties of the various botulinum toxins, reference is made to the article by Jankovic and Brin, *The New England Journal of Medicine*, No. 17, 1990, pp. 1186-1194, and to the review by Charles L. Hatheway in Chapter 1 of the book
35 entitled *Botulinum Neurotoxin and Tetanus Toxin*, L. L.

Simpson, Ed., published by Academic Press Inc. of San Diego, California, 1989, the disclosures in which are incorporated herein by reference.

5 The neurotoxic component of botulinum toxin has
a molecular weight of about 150 kilodaltons and is
thought to comprise a short polypeptide chain of about
50 kD which is considered to be responsible for the
toxic properties of the toxin, i.e., by interfering
10 with the exocytosis of acetylcholine, by decreasing
the frequency of acetylcholine release, and a larger
polypeptide chain of about 100 kD which is believed to
be necessary to enable the toxin to bind to the pre-
synaptic membrane. The "short" and "long" chains are
15 linked together by means of a simple disulfid bridge.
(It is noted that certain serotype of botulinum toxin,
e.g., type E, may exist in the form of a single chain
un-nicked protein, as opposed to a dichain. The
single chain form is less active but may be converted
20 to the corresponding dichain by nicking with a
protease, e.g., trypsin. Both the single and the
dichain are useful in the method of the present
invention.)

25 Immunotoxin conjugates of ricin and antibodies,
which are characterized as having enhanced cytotoxi-
city through improving cell surface affinity, are
disclosed in European Patent Specification 0 129 434.
The inventors note that botulinum may be utilized in
30 place of ricin.

 Botulinum toxin is obtained commercially by
establishing and growing cultures of *C. botulinum* in
a fermenter and then harvesting and purifying the
35 fermented mixture in accordance with known techniques.

Botulinum toxin type A, the toxin type generally utilized in treating neuromuscular conditions, is currently available commercially from several sources; for example, from Port Products Ltd. UK, under the trade name "DYSPORT," and from Allergan, Inc., Irvine, California, under the trade name BOTOX®.

It has been found, however, that some patients experience a loss of clinical responsiveness to botulinum toxin injections. One explanation for this action is that the patient has developed neutralizing antibodies or an immune response to, for example, botulinum toxin type A. Alternatively, the type of immune response may be different from just neutralizing antibodies. These include: (1) Allergic reaction where there is immediate local swelling, redness and itching. This may also be associated with general flu-like symptoms. (2) A delayed-type hypersensitivity manifested as swelling and redness at the injection site 48 to 72 hours after injection. (3) Or, a serum sickness-like response where the patient experiences flu-like symptoms. All of these immune-based reactions to type A dictate alternate serotype therapy to maintain clinical benefits.

A further hypothesis may explain loss of clinical responsiveness to botulinum toxin injections. This does not include interaction of other medications which may interfere with the action of botulinum toxin (i.e., angiotensin converting enzyme inhibitor class of antihypertensives and other endopeptidase inhibitors, aminopyridines, acetylcholine esterase inhibitors, etc.). One possible explanation for the loss of responsiveness is an alteration in the neuronal binding of toxin to the presynaptic

cholinergic nerve terminal. An alternation of gangliocides could reduce the binding efficacy of the toxin and thus reduce the amount of toxin internalized. Alternatively, an induction of proteases may cause an enhanced breakdown of the toxin either in the extracellular milieu or within the neuron. Finally, the neuron may change the amino acid composition of the target protein for the light chain of the toxin to reduce or eliminate its effect on the exocytotic mechanism.

It is one object of the invention to provide novel treatments of neuromuscular disorders and conditions with botulinum toxin type A followed with treatments of botulinum toxin types B, C, D, E, F and G.

SUMMARY OF THE INVENTION

The present invention provides a method of treating a neuromuscular disorder or condition such as strabismus and other disorders of ocular motility, e.g., comitant and vertical strabismus, lateral rectus palsy, nystagmus, dysthyroid myopathy, etc.; dystonia, e.g., focal dystonias such as spasmodic torticollis, writer's cramp, blepharospasm, oromandibular dystonia and the symptoms thereof, e.g., bruxism, Wilson's disease, tardive dystonia, laryngeal dystonia etc.; other dystonias, e.g., tremor, tics, segmental myoclonus; spasms, such as spasticity due to chronic multiple sclerosis, spasticity resulting in abnormal bladder control, e.g., in patients with spinal cord injury, animus, back spasm, charley horse etc.; tension headaches; levator pelvic syndrome; spina bifida, tardive dyskinesia; Parkinson's and limb (focal) dystonia and stuttering, etc. of a patient,

which method comprises administering to the patient suffering from said disorder or condition a therapeutically effective amount of a botulinum A followed with a neurotoxin of a different serotype, i.e., one
5 selected from the group consisting of botulinum toxin types B, C, D, E, F and G.

10 The clinical features of the above-listed neuromuscular disorders and conditions are described in Jankovic and Brin, cited above, and in Quinn, *Disorders of Movement*, Academic Press, 1989, all of which are incorporated herein by reference.

15 The present invention further provides compositions of said botulinum toxins in a vehicle suitable for injection of said toxins into the appropriate region of the patient to be treated. Alterations of the vehicle and excipient may include
20 materials designed to retain the injected toxin in the local area.

25 The present invention further provides a method for treating neuromuscular disorders or conditions in which the patient experiences a loss of clinical response to an initial treatment of botulinum toxin.

30 More specifically, a method in accordance with the present invention includes administering to the patient a therapeutically effective amount of botulinum toxin of a different serotype until the patient experiences loss of clinical response to the administered botulinum toxin and thereafter administering to the patient another botulinum toxin

of the selected serotype, said another botulinum toxin being administered in therapeutically effect amounts.

5 More particularly, the method in accordance with the present invention includes initial treatment with botulinum toxin type A followed by treatment with another botulinum toxin selected from the group consisting of types B, C, D, E and F.

10 Alternatively, the initial treatment may be with botulinum toxin type B followed by another botulinum toxin serotype selected from the group consisting of types A, C, D, E and F.

15 An alternative embodiment of the present invention includes the administration to a patient of a therapeutically effective amount of botulinum toxin of a selected serotype until the patient develops neutralizing antibodies and thereafter administration
20 to the patient of another botulinum toxin of a different serotype, said another botulinum toxin being administered in a therapeutically effective amount.

DETAILED DESCRIPTION

25 The botulinum toxins used according to the present invention are botulinum toxin serotype A, B, C, D, E, F and G.

30 Each serotype of botulinum toxin has been identified as immunologically different proteins through the use of specific antibodies. For example, if the antibody (antitoxin) recognizes, that is, neutralizes the biological activity of, for example,
35 type A it will not recognize types B, C, D, E, F or G.

While all of the botulinum toxins appear to be zinc endopeptidases, the mechanism of action of different serotypes, for example, A and E within the neuron appear to be different than that of type B. In addition, the neuronal surface "receptor" for the toxin appears to be different for the serotypes.

The physiologic groups of *Clostridium botulinum* types are listed in Table I.

Table I. Physiologic Groups of *Clostridium botulinum*

Group	Toxin Sero-Type	Biochemistry	Milk Digest	Glucose Fermentation	Lipase	Phages & Plasmids	Phenotypically Related <i>Clostridium</i> (nontoxigenic)
I	A,B,F	proteolytic saccharolytic	+	+	+	+	<u>C. sporogenes</u>
II	B,E,F	nonproteolytic saccharolytic psychotrophic	-	+	+	+	
III	C,D	nonproteolytic saccharolytic	+	+	+	+	<u>C. novyi</u>
IV	G	proteolytic nonsaccharolytic	+	-	-	-	<u>C. subterminale</u>

These toxin types may be produced by selection from the appropriate physiologic group of *Clostridium botulinum* organisms. the organisms designated as Group I are usually referred to as proteolytic and produce botulinum toxins of types A, B and F. The organisms designated as Group II are saccharolytic and produce botulinum toxins of types B, E and F. The organisms designated as Group III produce only botulinum toxin types C and D and are distinguished from organisms of Groups I and II by the production of significant amounts of propionic acid. Group IV organisms only produce neurotoxin of type G.

The production of any and all of the botulinum toxin types A, B, C, D, E, F and G are described in

Chapter 1 of *Botulinum Neurotoxin and Tetanus Toxin*, cited above, and/or the references cited therein. Botulinum toxins types B, C, D, E, F and G are also available from various species of clostridia. Currently fourteen species of clostridia are considered pathogenic.

Most of the pathogenic strains produce toxins which are responsible for the various pathological signs and symptoms. Organisms which produce botulinum toxins have been isolated from botulism outbreaks in humans (types A, B, E and F) and animals (types C and D). Their identities were described through the use of specific antitoxins (antibodies) developed against the earlier toxins. Type G toxin was found in soil and has low toxigenicity. However, it has been isolated from autopsy specimens, but thus far there has not been adequate evidence that type G botulism has occurred in humans.

In general, four physiologic groups of *C. botulinum* are recognized (I, II, III, IV). The organisms capable of producing a serologically distinct toxin may come from more than one physiological group. For example, Type B and F toxins can be produced by strains from Group I or II. In addition, other strains of clostridial species (*C. baratii*, type F; *C. butyricum*, type E; *C. novyi*, type C₁ or D) have been identified which can produce botulinum neurotoxins.

Preferably, the toxin is administered by means of intramuscular injection directly into a spastic muscle, in the region of the neuromuscular junction, although alternative types of administration (e.g.,

subcutaneous injection), which can deliver the toxin directly to the affected muscle region, may be employed where appropriate. The toxin can be presented as a sterile pyrogen-free aqueous solution or dispersion and as a sterile powder for reconstitution into a sterile solution or dispersion.

Where desired, tonicity adjusting agents such as sodium chloride, glycerol and various sugars can be added. Stabilizers such as human serum albumin may also be included. The formulation may be preserved by means of a suitable pharmaceutically acceptable preservative such as a paraben, although preferably it is unpreserved.

It is preferred that the toxin is formulated in unit dosage form; for example, it can be provided as a sterile solution in a vial or as a vial or sachet containing a lyophilized powder for reconstituting a suitable vehicle such as water for injection.

In one embodiment, the botulinum toxin is formulated in a solution containing saline and pasteurized human serum albumin, which stabilizes the toxin and minimizes loss through non-specific adsorption. The solution is sterile filtered (0.2 micron filter), filled into individual vials and then vacuum-dried to give a sterile lyophilized powder. In use, the powder can be reconstituted by the addition of sterile unpreserved normal saline (sodium chloride 0.9% for injection).

The dose of toxin administered to the patient will depend upon the severity of the condition; e.g., the number of muscle groups requiring treatment, the

age and size of the patient and the potency of the toxin. The potency of the toxin is expressed as a multiple of the LD₅₀ value for the mouse, one unit (U) of toxin being defined as being the equivalent amount
5 of toxin that kills 50% of a group of 18 to 20 female Swiss-Webster mice, weighing 20 grams each.

The dosages used in human therapeutic applications are roughly proportional to the mass of
10 muscle being injected. Typically, the dose administered to the patient may be up to about 1,000 units; for example, up to about 500 units, and preferably in the range from about 80 to about 460 units per patient per treatment, although smaller or larger doses may be
15 administered in appropriate circumstances.

As the physicians become more familiar with the use of this product, the dose may be changed. In the botulinum toxin type A, available from Porton,
20 DYSPORT, 1 nanogram (ng) contains 40 U. 1 ng of the botulinum toxin type A, available from Allergan, Inc., i.e., BOTOX®, contains 4 U. The potency of botulinum toxin and its long duration of action mean that doses will tend to be administered on an infrequent basis.

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Ultimately, however, both the quantity of toxin administered and the frequency of its administration will be at the discretion of the physician responsible
30 for the treatment and will be commensurate with questions of safety and the effects produced by the toxin.

The invention will now be illustrated by
35 reference to the following nonlimiting examples.

5 In each of the examples, the appropriate muscles
of each patient are injected with sterile solutions
containing the botulinum toxins. Total patient doses
range from 80 U to 460 U. Before injecting any muscle
group, careful consideration is given to the anatomy
of the muscle group, the aim being to inject the area
with the highest concentration of neuromuscular
junctions, if known. Before injecting the muscle, the
position of the needle in the muscle is confirmed by
10 putting the muscle through its range of motion and
observing the resultant motion of the needle end.
General anaesthesia, local anaesthesia and sedation
are used according to the age of the patient, the
number of sites to be injected, and the particular
needs of the patient. In accordance with the present
invention, multiple injections are necessary to
achieve the desired result, due to the patient's
experiencing loss of clinical response to an initial
treatment. Also, some injections, depending on the
20 muscle to be injected, may require the use of fine,
hollow, teflon-coated needles, guided by
electromyography.

25 Following injection, it is noted that there are
no systemic or local side effects and none of the
patients are found to develop extensive local hypoton-
icity. The majority of patients show an improvement
in function both subjectively and when measured
objectively.

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Example 1

The Use of Botulinum Toxin Serotype A, B and F
in the Treatment of Tardive Dyskinesia

5 A patient, suffering from tardive dyskinesia
resulting from the treatment with an antipsychotic
drug, such as haloperidol, is treated with an
effective amount of botulinum toxin type A by direct
injection of such toxin into the muscles identified by
10 the physician. After two to four days, the symptoms
of tardive dyskinesia, i.e., orofacial dyskinesia,
athetosis, dystonia, chorea, tics and facial
grimacing, etc., are markedly reduced. Upon continued
administration of the botulinum toxin type A, a loss
15 of clinical response is noted. Thereafter, an
effective amount of botulinum toxin type B is injected
and the symptoms of tardive dyskinesia continue to be
markedly reduced.

20 Example 1(a)

 The method of Example 1 is repeated, except that
a patient suffering from tardive dyskinesia is
injected with an effective amount of botulinum toxin
25 type A, followed by injection of an effective amount
of botulinum toxin type C. Similar results are
obtained.

30 Example 1(b)

 The method of Example 1 is repeated, except that
a patient suffering from tardive dyskinesia is
injected with an effective amount of botulinum toxin
35 type A, followed by injection of an effective amount

of botulinum toxin type D. Similar results are obtained.

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Example 1(c)

The method of Example 1 is repeated, except that a patient suffering from tardive dyskinesia is injected with an effective amount of botulinum toxin type A, followed by injection of an effective amount of botulinum toxin type E. Similar results are obtained.

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Example 1(d)

The method of Example 1 is repeated, except that a patient suffering from tardive dyskinesia is injected with an effective amount of botulinum toxin type A, followed by injection of an effective amount of botulinum toxin type F. Similar results are obtained.

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Example 2

Use of Botulinum Toxin in the Treatment
of Spasmodic Torticollis

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A male, suffering from spasmodic torticollis, as manifested by spasmodic or tonic contractions of the neck musculature, producing stereotyped abnormal deviations of the head, the chin being rotated to one side, and the shoulder being elevated toward the side at which the head is rotated, is treated by injection with up to about 300 units, or more, of botulinum toxin type E, (having an activity of one to four days) in the dystonic neck muscles. After the symptoms are substantially alleviated and the patient is able to

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hold his head and shoulder in a normal position, the patient develops antibodies. Thereafter the patient is injected with botulinum toxin type B and the symptoms continue to be substantially alleviated.

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Although there has been hereinabove described a use of botulinum toxin serotype for treating neuromuscular disorders and conditions in accordance with the present invention, for the purpose of illustrating the manner in which the invention may be used to advantage, it should be appreciated that the invention is not limited thereto since many obvious modifications can be made, and it is intended to include within this invention any such modifications as will fall within the scope of the appended claims. Accordingly, any and all modifications, variations, or equivalent arrangements which may occur to those skilled in the art, should be considered to be within the scope of the present invention as defined in the appended claims.

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